Reference Neutron Radiographs of Nuclear Reactor Fuel

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REFERENCE NEUTRON RADIOGRAPHS OF NUCLEAR REACTOR FUEL

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Abstract. Reference neutron radiographs of nuclear reactor fuel were produced by the Euratom Neutron Radiography Working Group and published in 1984 by the Reidel Publishing Company.

In this collection a classification is given of the various neutron radiographic findings, that can occur in different parts of pelletized, annular and vibro-compacted nuclear fuel pins. Those parts of the pins are shown where changes of appearance differ from those for the parts as fabricated. Also radiographs of those as fabricated parts are included.

The collection contains 158 neutron radiographs, reproduced on photographic paper (twice enlarged) and on duplicating film (original size).

INIS Descriptors: CALIBRATION; DEFECTS; FUEL PINS; IMAGES; NEUTRON RADIOGRAPHY; STANDARDIZATION.

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1. INTRODUCTION

For weldings and castings many standard reference radiographs were published as ASNI/ASTM standards. Also the IIW has issued similar collections of reference radiographs of welds. Therefore it was felt that a similar collection of standard reference radiographs will be needed in the field of neutron radiography of nuclear fuel. Thus the assessment of neutron radiographs of nuclear fuel elements can be faster and simpler if reference can be made to typical defects that can be revealed by neutron radiography.

One of the first tasks of the Euratom Neutron Radiography Working Group (NRWG), constituted in 1979, was to start standardization work by establishing a classification of defects revealed by neutron radiography of nuclear fuel and to collect adequate examples of corresponding neutron radiographs. Such a classification together with a collection of 36 neutron radiographs illustrating those defects was published in 1979 by Risø National Laboratory [1] and was accepted by the NRWG as a first step in its standardization activity.

Just recently, a new edition was published of a collection of reference neutron radiographs of neutron reactor fuel [2]. It contains 158 examples of defects in nuclear fuel as well as examples of its different parts as fabricated, assembled from different neutron radiography centers of the European Community, participating in the activities of the NRWG.

2. WHAT THE REFERENCE RADIOGRAPHS SHOW

It must be mentioned that in the reference radiographs published by ANSI/ASTM the term "discontinuity" is used, instead

of "defect". The illustrations of those discontinuities are graded or ungraded and each graded discontinuity type has several severity levels.

In the IIW collection of reference radiographs the term "defect" is used, and the radiographs have been divided into grades, graded in accordance with the relative importance of the different types of defects.

In the present collection of reference neutron radiographs the term "defect" is used to designate a change in appearance shown on an original radiograph of a particular part of the fuel as fabricated, to that shown on a subsequent radiograph, usually post-irradiation.

3. FUEL PIN COMPONENTS

In fig. 1 typical examples of nuclear fuel pins are given, containing pelletized, annular and vibro-compacted fuel.

The components of those pins are:

A. FUEL
A.a. Pellets
A.b. Annular fuel
A.c. Pellet-to-pellet-gap
A.d. Dishing
A.e. Vibro-compacted fuel
A.f. Fuel-to-clad-gap
A.g. Fuel column
A.h. Fuel composition

B. CLADDING

D. PLUGS
D.a. Bottom plug
D.b. Top plug

E. INSTRUMENTATION
E.a. Thermocouple
E.b. Pressure transducer
E.c. Diameter gauge
E.d. Length gauge
E.e. Other instrumentation

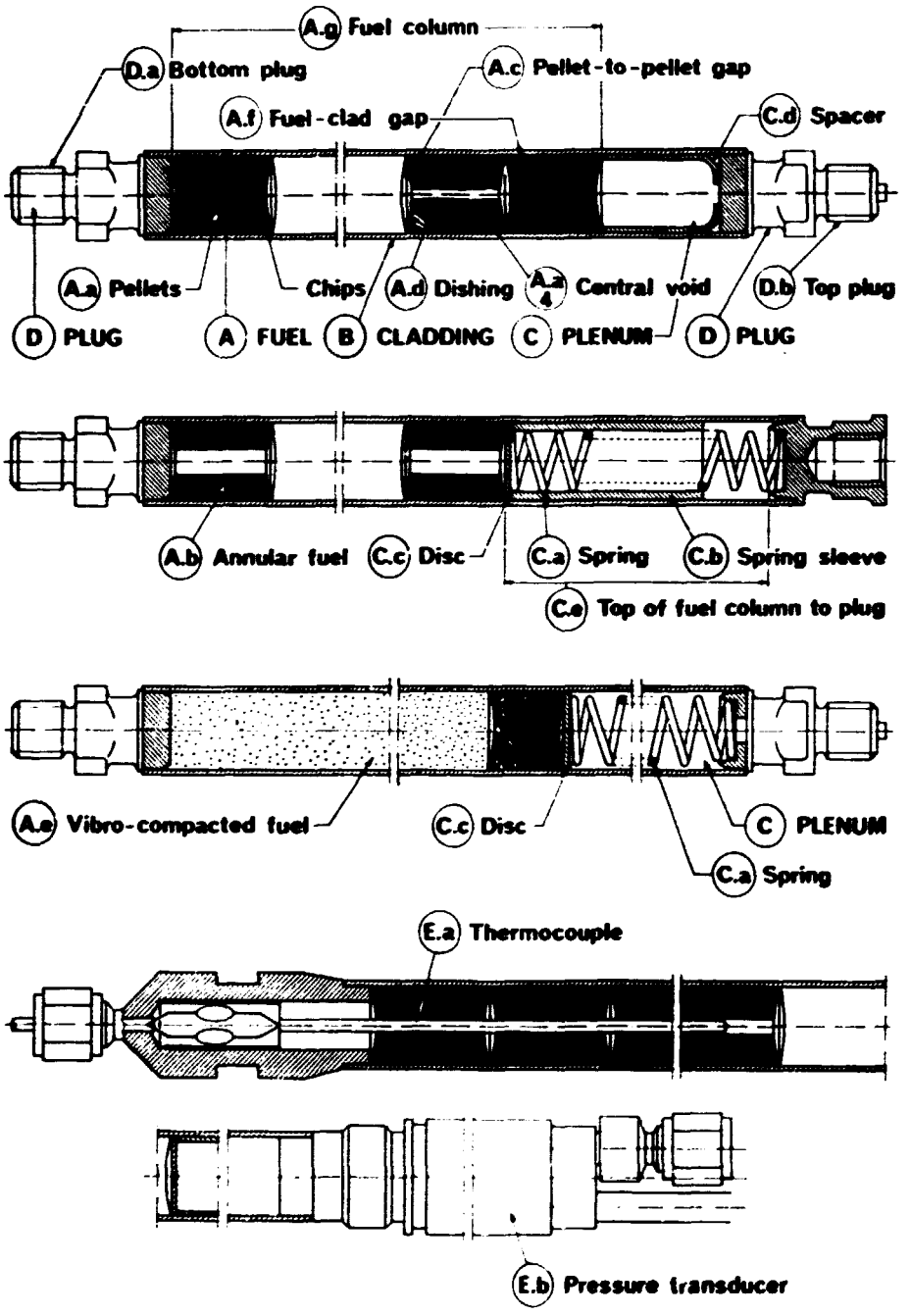

Fig. 1. Nuclear fuel pins components

C. PLENUM
C.a. Spring
C.b. Spring sleeve
C.c. Insulating disc
C.d. Spacer
C.e. Fuel column to plug distance

4. CLASSIFICATION OF FINDINGS

All of the nuclear pin components listed above are shown on the right side of fig. 2, whereas various differences in appearance from the fuel component as fabricated are listed at the top of fig. 2. They are the following:

0. (Fuel pin part) AS FABRICATED

1. CRACKS
1.1 Random
1.2 Longitudinal
1.3 Transverse
1.4 Annular
1.5 Stratified

2. CHIPS
2.1 Corner
2.2 Other
2.3 In pellet-to-pellet gap
2.4 Missing

3. CHANGE OF SHAPE OR LOCATION
3.1 Enlarged or swollen
3.2 Contracted
3.3 Filled-up or closed
3.4 Deformed
3.5 Broken
3.6 Dislocated
3.7 Extended
3.8 Accumulated
3.9 Restructured
3.10 Melted
3.11 Disintegrated
3.12 Migrated

4. VOIDAGE
4.1 In one pellet
4.2 Through several pellets
4.3 Through whole fuel column

6. CORROSION
6.1 Hydrides
6.2 Oxides
6.3 Other

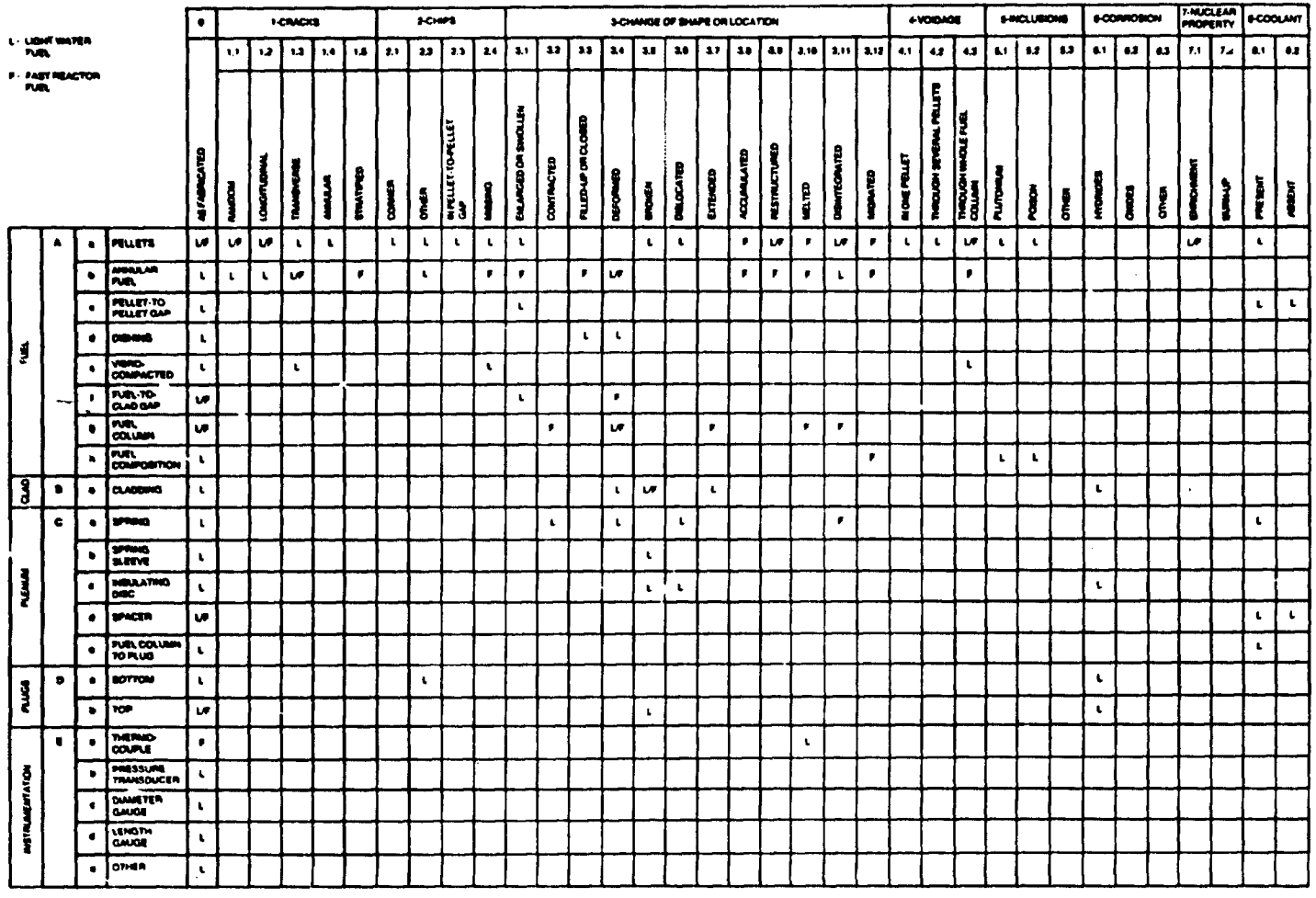

Fig. 2. Neutron radiographic findings in nuclear fuel

5. INCLUSIONS
5.1 Of plutonium
5.2 Of poison
5.3 Other

7. NUCLEAR PROPERTIES
7.1 Different enrichment
7.2 Different burnup

8. COOLANT
8.1 Present
8.2 Absent

As can be seen column "0" contains neutron radiographs of as fabricated fuel pin parts.

The neutron radiographic findings were selected from radiographs of light water (L) and fast (F) reactor fuel. If L of F is marked in fig 2 it means that in the collection |2| an example is given. It does not, however, mean that there cannot be such a finding if neither L nor F marking occurs. It means only that none of the participants of the NRWG has found such an example among his radiographs.

5. CONTENTS OF THE COLLECTION

The collection of neutron radiographs of nuclear reactor fuel |2| contains besides examples of nuclear pins components and a classification of neutron radiographic findings (described in 3 and 4 above) 158 copies and duplicating film (in original size) and on photographic paper (twice enlarged) of neutron radiographs taken on silver halide or nitrocellulose film.

A list of contents of the collection describes in detail the type of defect illustrated on the radiographs, as well as the type of nuclear fuel and the origin of the radiograph.

6. USE OF THE COLLECTION

The copies of the neutron radiographs on film can be viewed without removing them by illuminating the blank page which follows with a shaded desk lamp.

The reference radiograph may also be removed from the collection and be viewed on an illuminator together with the actual radiograph under assessment.

7. TERMINOLOGY

The text of this collection is produced both in England and French. Special terms used throughout the collection, as well as some useful ones in the field of neutron radiography, are reproduced in Danish, Dutch, English, French, German and Italian.

8. INSTALLATIONS IN THE EUROPEAN COMMUNITY

A survey on the main technical data and addresses of the neutron radiography installations in the European Community applicable for examination of nuclear reactor fuel is given at the end of the collection.
More technical details can be found in reference [3].

REFERENCES

[1] J. C. Domanus. Neutron radiographic findings in light water reactor fuel. Risø National Laboratory, Metallurgy Department, June 1979.

[2] J. C. Domanus (editor). Reference neutron radiographs of nuclear reactor fuel. D. Reider Publishing Co., 1984. EUR 8916 EN EP ISBN 90-277-1717-6.

[3] P. von der Hardt, H. Röttger (editors). Neutron radiography handbook. D. Reidel Publishing Company, 1981, EUR 7622e, ISBN 90-277-1378-2.

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